सत्यमेव जयते

भारत सरकार –GOVERNMENT OF INDIA
रेल मंत्रालय– MINISTRY OF RAILWAYS
(कार्यालयीन प्रयोग हेतु)– (For official use only)

Handbook on
Installation & Maintenance
Of
SOLAR PANEL

CAMTECH/S/PROJ/2013-14/HB-SP/2.0
November 2013

रेल अग्रदूत Transforming Railways

An ISO 9001-2008 Certified Organisation

EXCELLENCE IN MAINTENANCE

Indian Railways
Centre for Advanced Maintenance Technology

MAHARAJPUR, GWALIOR – 474 005

Click for contents

Click for contents

FOREWORD

Solar energy is one of the best forms of alternative energy sources as it is pollution free and available in abundance in nature. It can cater for various power supply requirements upto a great extent and it is the need of the hour. Solar panel which is the basic building block for obtaining power supply through solar cells has a wide range of applications in Indian Railways.

In view of the above and for keeping pace with the modern trends in solar power technology, CAMTECH have come up with this edition of handbook. It gives me great pleasure in presenting this handbook which covers latest information on Solar Panel. I am confident that this handbook will help the railway field personnel in improving their knowledge regarding solar panel, its installation and maintenance.

CAMTECH Gwalior **A.R.Tupe**
Date: 29.11.2013 **Executive Director**

Click for contents

PREFACE

On Indian Railways, Solar Panels have been installed at many stations in non-RE area where grid power supply is not available round the clock or not available at all. To impart knowledge about solar panel to the railway supervisors and maintainers, CAMTECH had prepared a maintenance handbook on Solar Panel in the year 2006. The technology is changing rapidly in every field and over the years there have been changes in the field of solar power technology too. To acquaint the field personnel with latest information, the handbook was taken up for review.

The current version of the handbook covers revised information on solar panel, its installation, maintenance and troubleshooting and supersedes the earlier version. A new section covering 'Designing a Solar Photovoltaic System' is also being added to help field engineers in deciding the number of Solar panels and battery capacity.

We are sincerely thankful to Shri S. Bandopadhyay, Sr.D.S.T.E./Bhopal/WC Rly., his sectional supervisors and maintainers who have helped us in preparing this handbook. We are also sincerely thankful to Shri A.K.Harnal, Asstt. General Manager SP (Marketing) from M/s Central Electronics Ltd., Sahibabad who have provided the latest information on the subject and helped us in reviewing the handbook.

Since technological upgradation and learning is a continuous process, you may feel the need for some addition/modification in this handbook. If so, please give your comments on email address dirsntcamtech@gmail.com or write to us at Indian Railways Centre for Advanced Maintenance Technology, In front of Adityaz Hotel, Maharajpur, Gwalior (M.P.) 474005.

CAMTECH Gwalior | **D.K.M.Yadav**
Date: 29.11.2013 | **Jt .Director (S&T)**

Click for contents

Click for contents

CONTENTS

Installation & Maintenance of Solar Panel

Click for contents

Go to Top of index

Click for contents

ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/S/PROJ/2013-14/HB-SP/2.0# XX date ....

Where “XX” is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

Sr. No. of Correction Slip	Date of issue	Page no. and Item No. modified	Remarks

Click for contents

DISCLAIMER

It is clarified that the information given in this handbook does not supersede any existing provisions laid down in the Signal Engineering Manual, Telecomm Engineering Manual, Railway Board and RDSO publications. This document is not statuary and instructions given are for the purpose of guidance only. If at any point contradiction is observed, then SEM, Railway Board/RDSO guidelines may be referred or prevalent Zonal Railways instructions may be followed.

OUR OBJECTIVE

To upgrade Maintenance Technologies and Methodologies and achieve improvement in Productivity and Performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability and Utilisation.

If you have any suggestion & any specific comments, please write to us:

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Click for contents

Section I
Solar energy and its applications

1.1 Introduction

The sources of conventional and non-renewable energy such as coal, petrol, diesel etc. are diminishing continuously on Earth, the formation of which is a long process. Hence a need for alternative energy sources was felt such as Wind energy, Bio-energy, Solar energy. These are called as non-conventional or renewable energy sources. Solar energy, which is abundant in nature and free of cost, is considered to be the best and most popular one.

Solar energy is obtained through the use of Solar cells. The Solar cells convert sunlight into electrical energy, based on the principle of photovoltaic effect. The electricity so obtained can directly be used to charge the batteries used for various appliances.

Indian Railways is also a consumer of electricity for general lighting, operation of rolling stock, Telecommunication and Signalling gears such as Signals, Point machines, Relays, Block instruments, Axle Counters etc. Hence solar energy has a wide range of applications in Indian Railways especially at remote or hilly places where grid supply is not available round the clock or not available at all.

1.2 Advantages and Disadvantages of Solar Panel

Advantages

- Fuel source for Solar Panel is direct and endless so no external fuels required.
- Sunlight - free of cost.
- Unlimited life of Solar Modules, fast response and high reliability.
- Can operate under high temperature and in open.
- Inherently short circuit protected and safe under any load condition.
- Pollution free.
- Minimum Maintenance
- Independent working
- Operation is simple and no electrochemical reaction and no liquid medium.
- Noise-free as there are no moving parts.
- No AC to DC conversion losses as DC is produced directly.
- No transmission losses as installed in the vicinity of the load.
- Suitable for remote, isolated and hilly places.
- Suitable for moving loads/objects
- Since it is in modular form, provision of future expansion of capacity is available.
- It can generate powers from milli-watts to several mega watts.
- It can be used almost everywhere from small electronic device to large scale MW power generation station.
- It can be installed and mounted easily with minimum cost.

Disadvantages

- Initial cost is high
- Dependent on sunlight
- Additional cost for storage battery.
- Climatic condition, location, latitude, longitude, altitude, tilt angle, ageing, dent, bird dropping, etc. affect the output.
- It has no self-storage capacity.
- Manufacturing is very complicated process.
- To install solar panel large area is required.

1.3 Utilization of Solar Power Supply System in the Indian Railways

The efficient running and control of Railway traffic in the country is sometimes seriously hampered by the irregular grid supply (by State Electricity Board) resulting in traffic congestion and other operational equipment failures also. The alternate D.G. sets pose considerable problem as it has a high maintenance cost and necessitates the use of additional D.G. sets as stand by. Again diesel oil is prone to pilferage, and moreover transportation and storage costs are involved. It also causes atmospheric pollution. Hence by harnessing the abundantly available and non-polluting by nature solar energy source for power requirements came into action after decades of research and field experience.

1.4 Application of Solar Powered System for Signalling & Telecommunications

Almost all signalling and Telecommunication gears can be run by solar power. In Indian Railway, Signalling system is Solar powered in phased manner. Priorities are given to those locations where there is no conventional power or power transmission through cables is cost effective. Some example of application of solar power for signalling and telecommunication gears are given below:

1. Semaphore signal lighting at night.
2. Charging battery to power Signal lighting and Point Machines.
3. Charging battery for Integrated Power Supply (IPS) system.
4. Charging battery for Optic Fibre Cable hut.
5. Solar powered Radio warning system/Gate Signal/HKT/TC.
6. Solar powered RRI/PI/relay operation (internal and external circuits)/ALR.
7. Charging secondary cells for Tokenless/Token block instruments.
8. Lighting Outer/Warner Signals and Distant Signal with motor operation.
9. Solar distillation plants.

1.5 Advantages of Solar Powered System for Signalling

Along with the advantages mentioned earlier the following are the additional advantages w.r.t. Signalling:

1. Totally Solid State design and highly desirable.
2. Power supply cabling from station building to the signal unit or cabin not needed, since the unit is a self contained power sources. This saves cabling cost.
3. Minimum maintenance, which can be easily done by low skilled worker.
4. Long life of whole system and the system gives trouble free performance.

5. System design suited to monsoon and low light condition thus ensuring failure free operation of the signalling gears throughout the year.

1.6 Photo Voltaic effect

Electricity can be generated directly from sunlight, by a process called photovoltaic effect, which is defined as the generation of an electromotive force as a result of the absorption of ionizing radiation. The photo voltaic effect can be observed in almost any junction of material that have different electrical characteristics, but the best performance to date has been from solar cells made of Silicon.

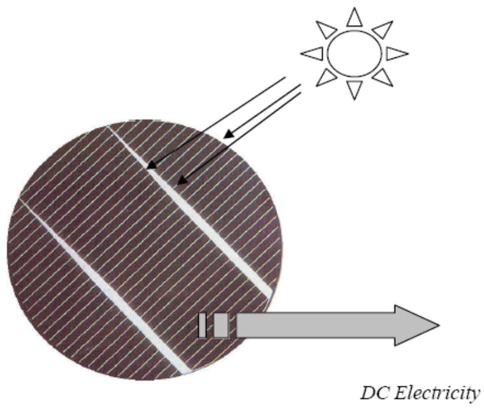

Fig.1.1: Photo Voltaic effect

1.7 Solar Cell: Construction & Working

The basic building block of a photovoltaic system is the Solar Cell, a semiconductor device having a simple p-n junction and which when exposed to sunlight produces DC electricity. The solar cell is made up of “Semi-Conductor” materials that are processed to make the device photovoltaic. The solar cell is made of single crystal silicon, polycrystalline and amorphous Silicon with an area of a few sq. centimeters to 200 sq. centimeters and even more. A thin p type silicon wafer is taken through phosphorus diffusion process and by screen-printing technology electrodes are made. The P-N junction of the solar cell gives rise to diode characteristics. Hence a solar cell is a PN junction device on which front and back electrical contacts are screen-printed. A sketch of typical psuedo-square solar cell is shown in Fig.2 (a) & (b). The side, which has negative polarity, is taken as front side and that which has positive polarity is taken as backside. The front or Negative side is exposed to sunlight for conduction to take place. Two Tinned copper strips work as terminal leads for interconnection to other cells. For collection of charge from the cell and conduction to terminal leads on negative side, Silver Oxide lines are screen printed horizontally and these are joined to terminal leads at close spacing (refer Fig 2 a). These lines cover only 5% of the total area of the cell, so that these do not pose any hindrance to the exposure of Sunrays. The back or Positive side is not exposed to sunlight; hence Aluminium is coated on whole surface for better conductivity (refer Fig 2 b). Aluminium is coated instead of Silver Oxide as latter is expensive hence not economical. The operation of solar cells involves these major processes:

i) Absorption of sunlight into semiconductor materials
ii) Generation of charge carriers.
iii) Separation of +ve & -ve charges to different regions of the cell to produce e.m.f.

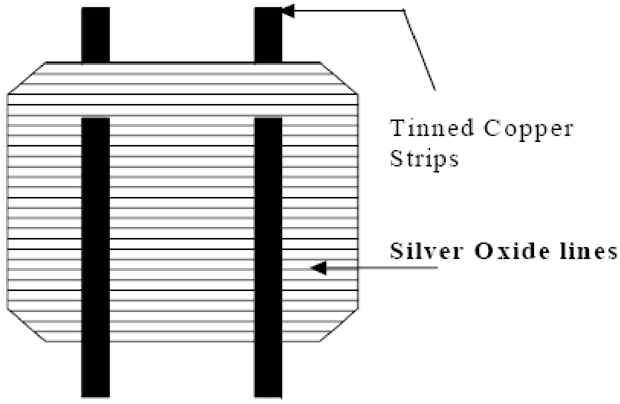

Fig 1.2 (a) Sketch showing front view of typical pseudo square solar cell

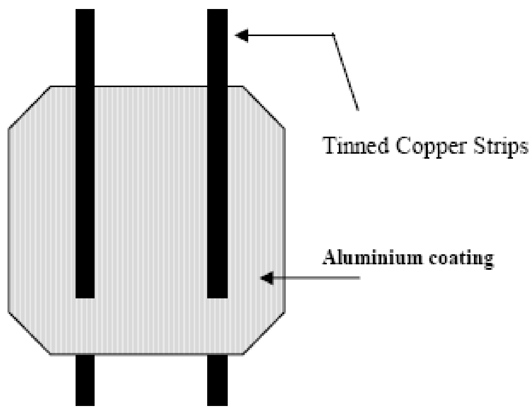

Fig 1.2 (b) Sketch showing rear view of typical pseudo square solar cell

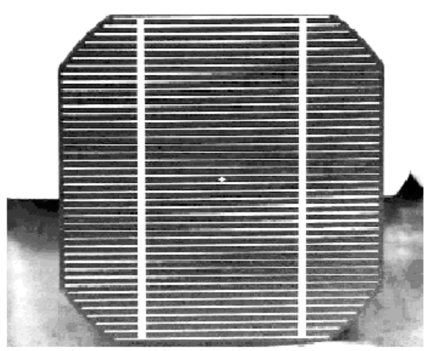

Fig. 1.2 (c): Solar Cell: Actual view

Click for contents

1.8 Solar Photo Voltaic (SPV) Module

The power generated by a single cell is small and therefore several cells are interconnected in series/parallel combination to get the required voltage and current. When a number of solar cells are connected in series to get a specific voltage the unit so formed is called as Solar Module. Charging batteries is the primary use of SPV module. Therefore normally 36 cells are joined in series to form a standard module, which is capable of charging 12 volts battery. A terminal box is provided on the backside of the module for external connections. A Bypass diode is connected across +ve and –ve in the terminal box. Cathode of the diode will be at +ve terminal and Anode will be at –ve terminal of the module. This diode protects the module cells from overheating due to shadowing of the module or any cell breakage Generally the rating of bypass diode is 1.52 times of the maximum current of module. The Repetitive Reverse Peak Voltage Vrrm of the diode should be double the string open voltage. For Indian Railways Solar Photovoltaic Module is manufactured as per RDSO Specification No. IRS:S 84/92 with latest amendment. A typical solar module is shown in Fig 1.3.

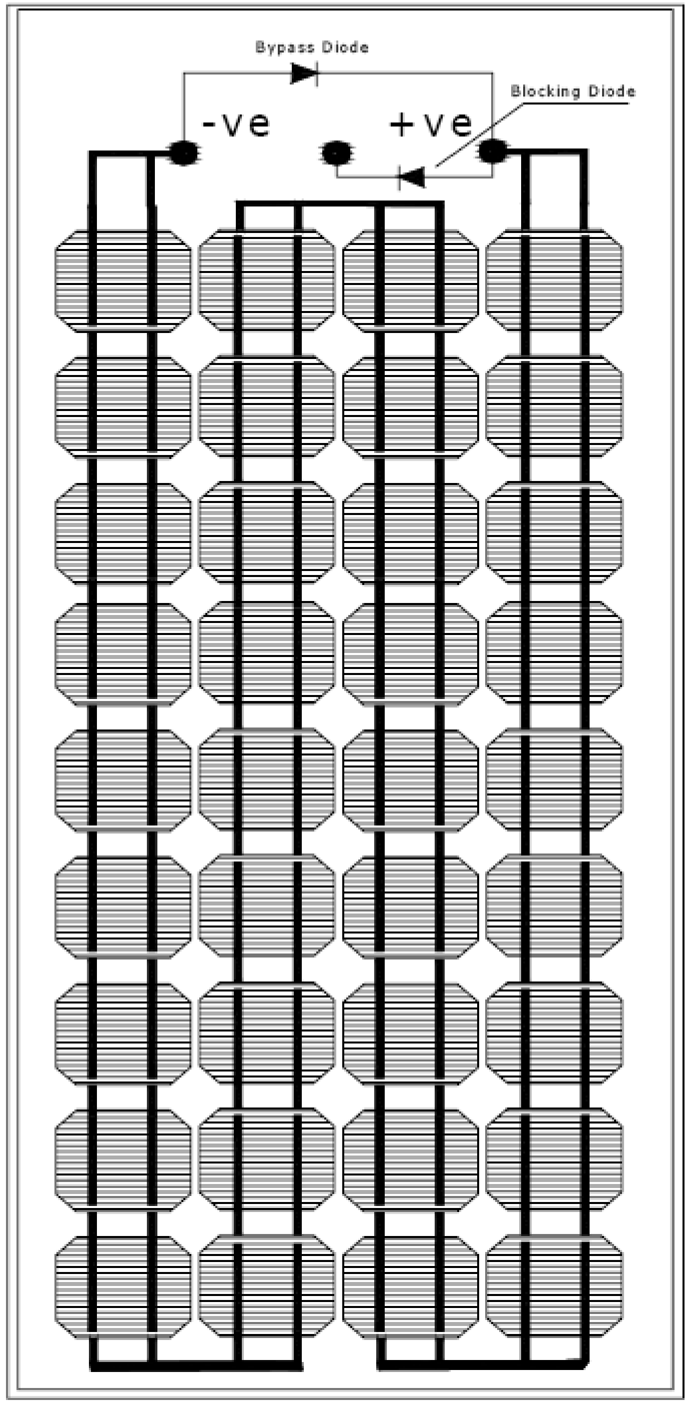

Fig.1.3: Solar Module

Click for contents

1.9 Solar Panel

A Solar panel consists of a number of solar modules, which are connected in series and parallel configuration to provide specific voltage and current to charge a battery. A diode is connected on the +ve terminal of such string in forward bias. This is called Blocking diode. This diode is provided so that in daytime current can flow from module to battery, but at night or in cloudy day current should not flow back from battery to module or from one string to another string Drawing shown in Fig 4 below illustrates a Solar panel.

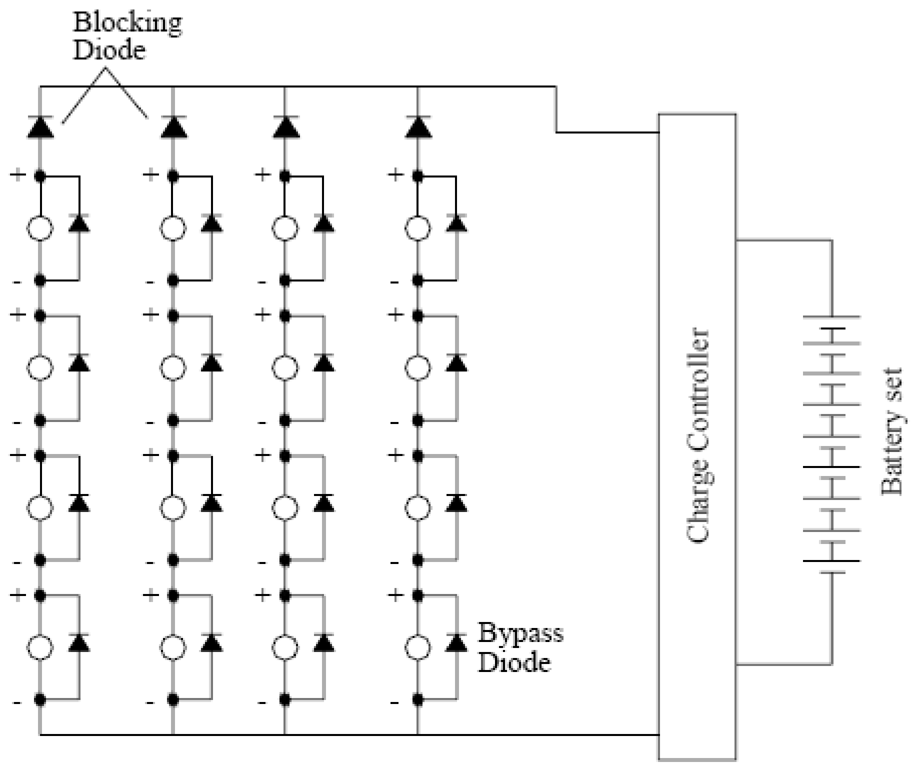

Fig.1.4: Structure of a Solar Panel

1.10 Main Components of Solar Photo Voltaic System

The solar power system consists of the following components:

i. Solar array.
ii. Battery Bank
iii. Solar Charge Controller
iv. Field Junction Box
v. Solar Module Mounting Structure
vi. Earthing kit
vii. Cables.

Click for contents

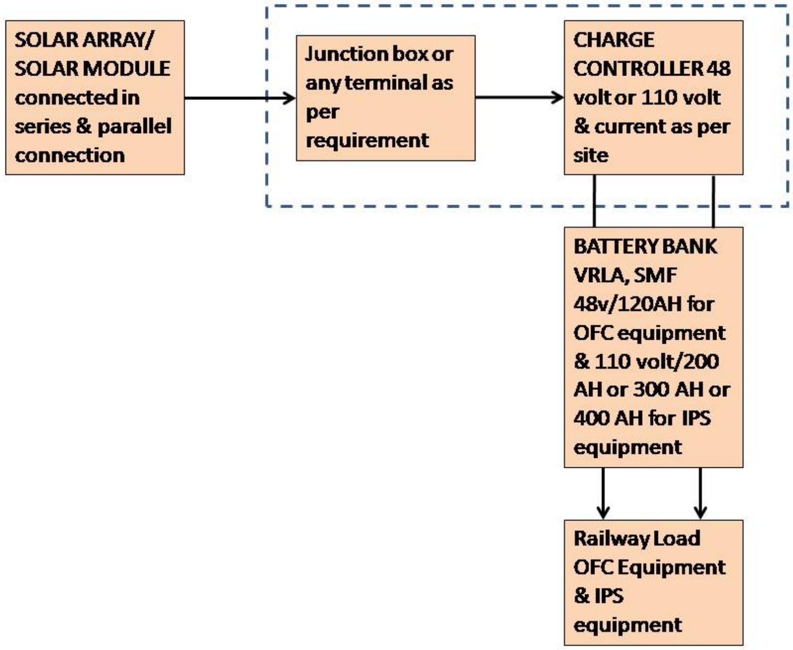

Fig.1.5: Block diagram of Solar Photo Voltaic System

1.10.1 Solar Array

Solar array consists of series/parallel combination of modules, which are mounted on the metallic structure in sunny and shadow free area at a fixed angle as recommended by designer. All the modules will face the South in Northern hemisphere. Cables from the array area will come to the control and battery room through junction boxes from panels of modules.

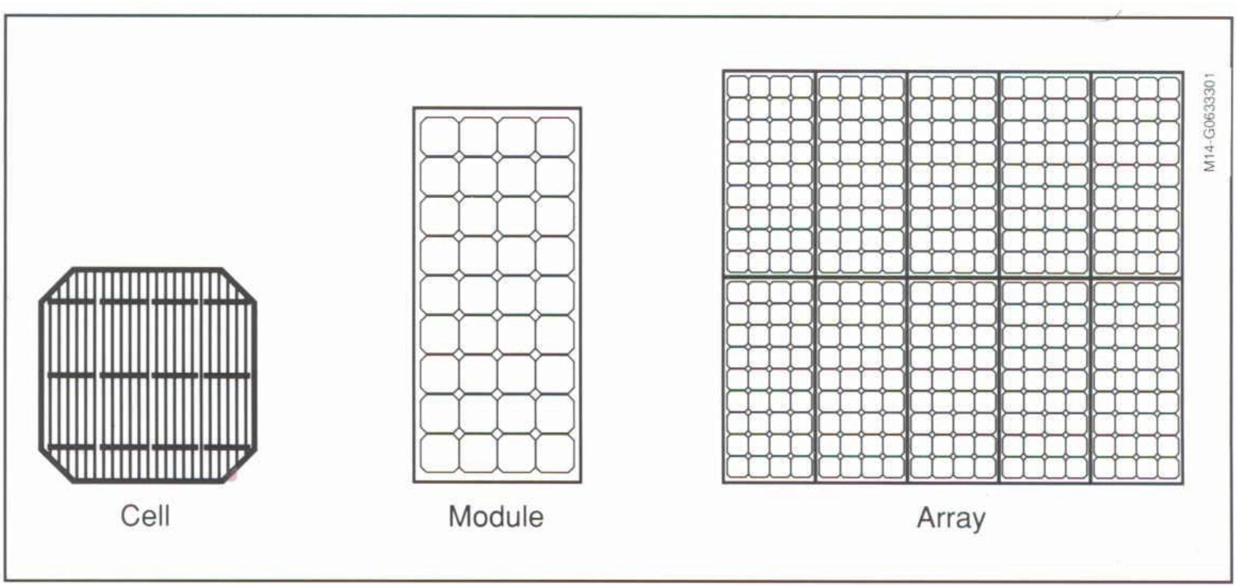

Fig.1.6: Sketches showing Cell, Module and Array

Click for contents
Click for contents

1.10.2 Battery Bank

The Sun is not always available and it is not regular. However, loads are to be fed any time of the day. Therefore power should be stored in a battery bank. Low maintenance Lead acid battery as per IRS: S 88/2004 or latest of specified capacity will be provided. The capacity of this battery bank is given in Ampere - Hour (AH) and bus bar voltage. The bus-bar voltage is decided by the voltage requirement of the load.

1.10.3 Solar Charge Controller

Charge controller is the interface between Array and battery bank. It protects the battery from overcharging and moderate charging at finishing end of charge of battery bank. Therefore it enhances the life of the battery bank. It also indicates the charging status of batteries like battery undercharged, overcharged or deep discharged through LEDs indications. Some switches and MCBs are also provided for manual or accidental cut-off of charging. In some charge controllers load terminals are also provided through a low battery charge cut-off device so that it can protect the battery bank from deep discharge. Solar Charge Controller units for Indian Railways are manufactured as per RDSO Specification No.RDSO/SPN/187/2004. The front view of a typical CEL make Charge Controller is shown in Fig.1.7.

Fig.1.7 : Front view of a Charge Controller

The technology adopted nowadays for manufacturing solar charge controller is MOSFET/IGBT technology. With this technology the idle current of the controller is less than 50 mA depending upon the rating of the charge controller and its current. First the controller is connected to battery bank and then it is connected to Solar Array/Solar module for sensing the voltage from the module. When the system is put into operation, the SPV modules start charging the battery bank. Care should be taken that in no case the battery connections are removed from the controller terminals when the system is in operation, otherwise SPV voltage may damage the Charge controller, since the Solar voltage is always higher than the battery voltage.

LED indications of Charge Controller

Sr. No.	LED Colour	Indication
1.	GREEN	Boost Charging (SPV1 & SPV2)
2.	YELLOW	Float Charging (SPV)
3.	RED	Battery LOW
4.	RED	Battery REVERSE with Alarm
5.	RED	PV REVERSE with Alarm

1.10.4 Field Junction Box (FJB)

FJB is the interface between Solar panels and the Charge Controller. All the incoming/outgoing cables/wires from Solar panel to Charge Controller are terminated at FJB.

Fig.1.8 : A typical FJB

1.10.5 Solar Module Mounting Structure

This is made up of galvanized iron frames and angles. In this structure flexibility is provided to change the module-mounting angle seasonally. This structure is grouted by small civil work and modules are mounted subsequently. Also, this mounting structure should be earthed suitably at several places if voltage of the array is more than 50 Volts.

1.10.6 Earthing kit

Earthing kit is provided to earth the mounting structure. Provision of earthing shall be done as follows:

The installation shall have proper earth terminals and shall be properly earthed.

Zonal Railways shall provide earthing arrangement as per IS:S 3043 and directions issued by RDSO for Lighting and Surge protection for signaling equipment vide letter No. STS/E/SPD dated 22.06.2004. The earth resistance shall not be more than 2 ohm. Earth provided shall preferably be maintenance free using earth resistance improvement material.

1.10.7 Cables

We require different types of cables to connect module to module, modules to charge controller, charge controller to battery, or connect battery to load as required. The cable size used for interconnection of SPV module, Charge Controller and battery shall be minimum 2 X 2.5 sq. mm Cu. Cable. As far as some hardware is concerned the screws and bolts/nuts are of Chrome plated, stainless steel and brass so that rusting should not be take place.

Click for contents

1.10.8 Operation

Operation of the Solar power source is very simple. Once the system is installed, CHG. ON (Green) LED will glow during daytime and will indicate that the power is available for charging Battery Bank from SPV panel. Connect the equipment to be operated on solar power to the SPV Charge Control Unit at terminals marked ‘LOAD’ position.

1.11 Types of Solar Panels

Solar panels are classified on the basis of the following points :

1) Crystalline Silicon (Mono/Poly/Amorphous)
2) Different Size or Area of cells
3) Type of cells & nos. (Rectangular/Circular/Square/ Pseudo-square/Semi-circular etc.)
4) Power (High/Mid/Low range)

Go to Index

Click for contents

Click for contents

Section II

Designing a Solar Photovoltaic System

2.1 Definitions

The following definitions are very important in designing a solar photo voltaic system.

Solar Cell

The basic photovoltaic device, which generates electricity when exposed to sunlight, shall be called a “Solar Cell”.

Solar Module

The smallest complete environmentally protected assembly of interconnected solar cells shall be called “Module”.

Solar Panel

A group of modules fastened together, pre-assembled and interconnected, designed to serve as an installable unit in an Array shall be called “Panel”.

Solar Array

A mechanically integrated assembly of modules or panels together with support structure, but exclusive of foundation, tracking, thermal control and other components, as required to form a dc power producing unit shall be called an “Array”.

Solar irradiation

On any given day the solar radiation varies continuously from sunrise to sunset and depends on cloud cover, sun position and content and turbidity of the atmosphere.
The maximum irradiance is available at **solar noon** which is defined as the midpoint, in time, between sunrise and sunset. The total solar radiant power incident upon unit area of an inclined surface (Watt/m^2) is called total solar irradiance.

Insolation

Insolation differs from irradiance because of the inclusion of time. Insolation is the amount of solar energy received on a given area over time measured in kilowatt-hours per square meter squared (kW-hrs/m^2) - this value is equivalent to "**peak sun hours**".

Peak Sun Hours

Peak sun hours is defined as the equivalent number of hours per day, with solar irradiance equaling 1,000 W/m^2, that gives the same energy received from sunrise to sunset.
Peak sun hours is of significance because PV panel power output is rated with a radiation level of 1,000W/m^2.
Many tables of solar data are often presented as an average daily value of peak sun hours (kW-hrs/m^2) for each month.

Click for contents

Conversion Efficiency

The ratio of the maximum power to the product of area and irradiance expressed as a percentage.

$$n = \frac{\text{Maximum power}}{\text{Area x irradiance}} \times 100\%$$

2.2 General & Technical requirements for Solar Photo Voltaic Module

Following are the general and technical requirements of solar photovoltaic module for use in Railway S&T installation for the correctness of its material, design and electrical characteristics as per IRS specification IRS:S 84-92

2.2.1 General Requirements

The solar module for the purpose of this specification shall consist of the following three main components:

(i) Toughened front glass.
(ii) A suitable mounting frame.
(iii) An assembly of suitably interconnected, silicon solar cells working on the principle of photovoltaic conversion of sunlight into electricity.

The silicon wafers cut from the large crystal shall be polished and necessary chemical treatment shall be given to achieve requisite surface characteristics for optimum efficiency of individual cells.

P-N junction on individual wafer shall be made by injecting impurity (phosphorous or any other suitable material) by diffusion process.

The solar cells required to form a module shall be connected in series/ parallel through tinned copper foils. These shall be mounted behind a high transparency, toughened glass front surface. Two thin transparent films of suitable plastic material, preferably (Ethylene Vinyl Acetate) shall be interposed between the solar cell layer and the front glass and the solar cell layer and the back plastic laminate. This assembly shall then be kept in a temperature controlled oven at a suitable temperature, so that the above assembly becomes a solid mass with the cells protected against corrosion, moisture, pollution and weathering.

The transparency of toughened glass used shall not be less than 91%. A certificate to this effect shall be submitted by the supplier. A copy of test results from a recognized test house or their own laboratory shall be submitted at the time of type approval.

The complete solar module shall be sealed in an Anodized Aluminium Frame with RTV silicon rubber compound filling around the edges to give further moisture barrier and shock resistance.

The output terminals of the module shall be provided on the back of the solar PV-module. Terminal block shall be made of Nylon-6. It shall be housed in a HDPE-UV stable junction box secured physically uniformly to the frame of the PV module. The junction box should have a hinged lid with self-holding fasteners enabling easy handling. The box lid should be secured with a gasket for greater protection against ingress of moisture (conforming to IP-55) of IS: 2147-62). Cable outlets from solar PV module terminal shall be through cable glands to be provided in the junction box (with addl. knockouts provided) to help in series /parallel connection of solar PV modules. The junction box should have common terminals with suitable by pass diodes for prevention of hot spot problem.

If required by the purchaser the module shall be fixed on a mounting bracket, which shall be suitably designed to withstand the weight of the panel. The mounting arrangement shall be suitable for pole mounting, column mounting or flat surface, as desired by the purchaser.

Provision for directional and angular adjustment shall be provided to get maximum utilization of incident sunlight.

The design/drawings of the mounting bracket shall be supplied along with the module to the purchaser.

The supplier shall give information regarding the weight and dimensions of the module, to the purchaser.

The solar photovoltaic module shall be highly reliable, light-weight and shall have a long operational life.

The recommended values of output power from each module are 4, 6, 9, 12, 30, 32, 35, 40, 50, 70, 80 & 100 watts. The purchaser shall, however, specify the output wattage of the module required by him.

The recommended nominal voltages of each module are 4, 6, 9, 12 & 24Volts. The purchaser shall, however, specify the voltage of the module required by him.

2.2.2 Technical requirements

Some of the important technical requirements as per IRS:S 84-92 are as given below:

The following parameters shall be clearly specified by the manufacturer for different type of solar modules manufactured by him:

a) Peak power output (Pm)
b) Current at peak power output (Im)
c) Voltage at peak power output (Vm)
d) Short circuit current (Isc)
e) Open circuit voltage (Voc)
f) Conversion efficiency of the module (n)

Click for contents

The values of parameters from (a) to (f) above shall be specified under standard test conditions of

(a) Cell junction temperature of 25 ± 2ºC.
(b) Irradiance of 1000 Watt/M.Sq. as measured with a reference solar cell (duly certified by a recognized national/international test house/lab. nominated for this purpose.
(c) Standard Solar spectral energy distribution.
(d) Air Mass of 1.5.

The frame of the mounting fixture shall be made of anodized aluminium, conforming to specification IS: 7088-1973 with 20 micron anodization thickness. All other parts such as fasteners etc. shall be made of galvanized or stainless steel to make them weather-proof. In addition to holes provided for fixing on to mounting structure, extra holes are to be provided suitably in the frame for cable routing.

The solar module shall be able to withstand a maximum mean hourly rainfall of 40 mm.

The solar module shall be able to withstand humidity level of upto 95%.

The conversion efficiency of the modules upto 35W shall not be less than 8% and for modules greater than 35W shall not be less than 12%.

The cell efficiency of the solar cells shall be greater than 12%.

If required by the purchaser, the back plastic laminate shall be replaced by a toughened glass sheet to make the module suitable for use in coastal areas/industrially polluted areas/places where the plastic laminate is likely to get corroded.

If required by the purchaser, an aluminum backing plate to protect the module from miscreants shall be provided.

2.3 Primary phases of designing an SPV system

The primary phases of designing a Photovoltaic system consists of the following steps:

1. Planning
2. Collection of information/data
3. Load calculation
4. Sizing Solar Array
5. Deciding Battery capacity
6. Selection of Charge Controller
7. Deciding Inverter capacity
8. Structure
9. Wiring

2.3.1 Planning

Before designing a solar photovoltaic system, several considerations are to be kept in mind such as

- The cost of the system should not be unusually high and at the same time the quality should also not suffer.
- Initial costs and lifetime costs shall also be taken into consideration.
- The system should be simple in design as far as possible with high reliability and efficiency.
- Whether central generation is beneficial or distributed is to be worked out.
- The system to be planned so as to cater for expected future growth.
- Prevention of improper load to be ensured.

2.3.2 Collection of Information/data

Following types of information are to be gathered

(i) Load/ Application

- Voltage system e.g. AC or DC or both
- Operating voltage range of load
- Daily consumption
- Daily duty cycle
- Criticality of loads
- Monthly / Weekly load profile

(ii) Climatic conditions

- Insolation
- Latitude, Longitude
- Temperature
- Accessibility to site
- Terrain
- Local Knowledge

(iii) User compatibility

- Understanding technical issues.
- Maintenance schedules and mentality.
- Whether the controls are field adjustable.
- Budget constraints
- Understanding of managing energy budget.

Click for contents

2.3.3 Load calculation

For DC Loads

Load Amps X Operating Hours per Day = Amp Hour Per Day (AHPD)
(If Load is available in watts, divide the wattage by system voltage to get Amps)
(Multiply by % duty cycle if data available)

For AC Loads

AC Watts X Operating Hours per Day = Watt Hours Per Day (WHPD)
AHPD = WHPD / (Inverter Efficiency X Nominal System Voltage)

2.3.4 Sizing Solar Array

No. of Series Modules = Nominal DC System Voltage / Nominal Voltage of Solar Module

No. Of Parallel Modules = AHPD / {(1- Module derating*) X Battery AH Efficiency X Im of Module X Solar Insolation of the worst Month}

No of Modules in Solar Array = No of Series Modules X No of Parallel Modules

Capacity of Solar Array = No of Modules X Capacity of Each Module

** Derating ~10% on account of dust, mismatch, orientation etc.*

2.3.5 Deciding Battery capacity

For calculating the capacity and number of batteries, first the number of back up days are to be decided, based on No. of Consecutive sunless days.

For Example Back up days for residential load = 3 to 5 days
Back up days for Industrial Load = 7 to 14 days
Back up days for poor weather = 7 to 14 days

Check Manufacturer's Recommended Maximum Depth of Discharge (DOD) Normally it is
80% for deep cycling
59% for shallow cycling

Check the temperature variations of site and determine the Maximum DOD as per data given by battery manufacturer.

Battery Capacity (In AH) = (AHPD X No. of back up days) / Max DOD

No of series Batteries = System DC Voltage / Battery Voltage

No of Parallel Batteries = Total AH Required / AH of Individual Battery

Click for contents

2.3.6 Selection of Charge Controller

Charge controllers are included in most PV systems to protect the batteries from overcharge and/or excessive discharge. The minimum function of the controller is to disconnect the array when the battery is fully charged and keep the battery fully charged without damage.

The charging routine is not the same for all batteries. A charge controller designed for lead- acid batteries should not be used to control NiCd batteries.

Charge controllers can be used in parallel to add more modules to a battery bank.

Salient feature of Charge controller

- Power devices should be of Solid state, High efficiency with Two stage charging technique.
- Protection against Transient/Surge.
- Prevent discharge of battery through solar panel during night.
- Protection against overcharge of the battery.
- Protection against reverse connection of battery and module.
- Robust enclosure and cooling with heat sink.
- Control, temperature compensated set points and equalization.
- Suitable MCB's provided at Solar input of 100 Amp.

Typical per cell voltages at ambient temperature 24º - 25º C

Boost charging upto	: 2.34 V
Float stage voltage maintains	: 2.29 V
Boost stage reactivates at	: 2.14 V
Battery low at	: 1.74 V

Calculate total current that Charge Controller will control

No. of Parallel Modules X Isc X 1.25 = Charge Controller Capacity

(Few manufacturers already have built in extra current capacity)

2.3.7 Module mounts

While mounting the modules, following points should be considered for getting maximum output from the solar modules:

- Modules should be oriented to face the Sun.
- The Modules produce more power when cooler.
- The mounting and color of the modules can sometimes be chosen to blend with the architecture.
- Tracking the Sun increases the amount of power from an array

2.3.8 Structure

Select type of structure i.e Ground Mount, Rooftop Mount, Pole Mount or Tracker.

A group of Modules mounted on single unit of structure and interconnected together is called PANEL.

Calculate Number of Structures by following formula

Click for contents

No. of Structures = Total No. of Modules / No. of Modules on single unit of st.

Group of panels connected through junction box will make Array.

While designing structure provision for future growth should be considered

2.3.9 Wiring

Selecting the correct size and type of wire will enhance the performance and reliability of PV system. The size of the wire must be large enough to carry the maximum current expected without undue voltage losses.

All wire has a certain amount of resistance to the flow of current. This resistance causes a drop in the voltage from the source to the load. Voltage drops cause inefficiencies, especially in low voltage systems (12V or less).

Typical Values of Module current and voltages are provided by the manufacturer. Based on system voltage and current decide size of wire/cable to be used for module interconnection.

Calculate output current and voltage of the panel and decide specifications of wire/cable for panel interconnection. Always use minimum possible wire lengths.

Always use suitable lugs, connecters etc for connection.

Decide number and type of switches, fuses and circuit breakers as per load, system and user requirement.

2.4 Sample system design

The designing of a system can be better understood by the following example:

Step 1: Determine the DC load

DC load of a device 1 = No. of DC devices X Device Watts X Hours of daily use
= DC Watt Hours per Day (1)

Similarly calculate the DC load of other devices.

Suppose Total DC Watt Hours per Day of such devices = [A]

Step 2: Determine the AC load and convert to DC

AC load of a device 1 = No. of AC devices X Device Watts X Hours of daily use
= AC Watt Hours per Day (1)

Similarly calculate the AC load of other devices.

Suppose Total AC Watt Hours per Day of such devices = (B)
Divide by 0.9 (Inverter, losses) to convert into DC

Suppose Total DC Watt Hours per Day of such devices = [B]

Step 3: Determine the Total System load

Suppose total DC load [A] = 2000 Watt Hours per Day
& total DC load [B] = 1500 Watt Hours per Day

Total System Load [A+B] =3500 Watt Hours per Day

Step 4: Determine Total DC Ampere Hours per Day

i.e. Total System Load/System Nominal Voltage
= 3500 Watt Hours per Day/48 Volts
= 73 Ampere Hours per Day

Step 5: Determine Total Ampere Hours per Day with Batteries

i.e. Total Ampere Hours per Day/(Battery efficiency X Module derating)
= 73/(0.9 X 0.9)
=73/0.81
= 90.12
$\simeq$ 100 Ampere Hours per Day

Step 6: Determine the Total PV Array Current

i.e. Total Daily Ampere Hour requirement / Design Insolation*
=100 Amp-hrs / 5.0 peak solar hrs
= 20 Amps
* Insolation Based on Optimum Tilt for Season

Step 7: Select PV Module type

For example
Choose CEL PM 75 module:
Max Power = 75 W (@STC)
Max Current = 4.41 Amps
Max Voltage = 17 Volts

Step 8: Determine Number of Modules in Parallel

i.e. Total PV Array Current / (Module Operating Current)
= 20 Amps / (4.41 Amps/Module)
= 4.5
$\simeq$ 5Nos.of modules

Step 9: Determine Number of Modules in Series

i.e. System Nominal Voltage / Module Nominal Voltage
= 48 Volts / (12 Volts/module)
= 4 Modules

Step 10:Determine Total Number of Modules

Number of modules in parallel X Number of modules in Series
= 5 X 4 = 20 modules of 75 Watt each i.e. 1500Wp

Step 11: Determine Minimum Battery Capacity

[Total Daily Amp-hr per Day with Batteries (Step 5) X Desired Reserve Time (Days)] / Percent of Usable Battery Capacity

= (73 Amp-hrs/Day X 3 Days) / 0.80

= 274

$\simeq$ 300 Amp-hrs

Step 12: Choose a Battery

Use Flooded Lead Acid Battery Cells

Nominal Voltage = 2 Volts No. of cells =24

Rated Capacity = 100 Amp-hrs

(3 Strings in Parallel)

Or

Nominal Voltage 6Volts, No. of Batteries = 8(series)

Rated Capacity 150 AH, 2 Strings in Parallel

Step 13: Choose Charge Controller

No. of Parallel Modules X Isc X 1.25 = Charge Controller Capacity

5 x 5x 1.25 = 31.25 Amps (Nearest higher available Value may be selected)

e.g. 48 Volts 40 Amps may be chosen.

Step 14: Choose Inverter

AC Watts on Inverter = Total AC Watts of AC devices X 25% extra.

Inverter of nearest higher rating may be chosen to cater for surge.

2.5 Solar Panel Requirement for IPS System at PI Station in Non-RE Area

RDSO has standardized the Solar Panel requirements for IPS System at Panel Interlocked Station in Non- RE area based on the assumption that all three sources of supply i.e. solar power, AC commercial supply and DG set supply will be utilized everyday for running signalling system at a station. Battery capacity has already been specified as 300 AH for IPS system in non-RE area. These requirements are separately worked out for up to 3 line station, 4 line station, 6 line station and 4 line station with DC LED Signals, and are tabulated in Table A below:

TABLE A

Sr. No.	**Description**	**Upto 3 line station**	**Upto 4 line station**	**Upto 6 line station**	**Upto 4 line station with DC lit LED signal**
1.	**Approximate Signalling load (AC + DC) except track circuit at 110 V**	13A	22A	28A	16A

Click for contents

Sr. No.	Description	Upto 3 line station	Upto 4 line station	Upto 6 line station	Upto 4 line station with DC lit LED signal
2.	**Required from solar power (in AH)**				
(a)	For 12 hrs. load per day	12x13= 156 AH	12x22= 264 AH	12x28= 336 AH	12x16= 192 AH
(b)	For 10 hrs. load per day	10x13= 130 AH	10x22= 220 AH	10x28= 280 AH	10x16= 160 AH
(c)	For 08 hrs. load per day	08x13= 104 AH	08x22= 176 AH	08x28= 224 AH	08x28= 224 AH
(d)	For 06 hrs. load per day	06x13= 78 AH	06x22= 132 AH	06x28= 168 AH	06x16= 96 AH
3.	**SPV requirement for 110 V system**				
(i)	Derating factor of Solar Panel	10% (0.9)	10% (0.9)	10% (0.9)	10% (0.9)
(ii)	Derating factor of Battery efficiency	10% (0.9)	10% (0.9)	10% (0.9)	10% (0.9)
(iii)	Sun availability assumed	5 Hrs.	5 Hrs.	5 Hrs.	5 Hrs.
(iv)	Charging current of Solar panel	4.2 A	4.2 A	4.2 A	4.2 A
(v)	No. of 12 V, 70 W Solar Panels required in parallel				
(a)	For 12 hrs. load per day	156/(0.9X0.9X 5X4.2) =10 Nos.	264/(0.9X0. 9X5X4. 2) =16 Nos	336/ (0.9X0.9X5X4.2) =20 Nos	192/ (0.9X0.9X5X4.2) =12 Nos
(b)	For 10 hrs. load per day	130/ (0.9X0.9X 5X4.2)=0 8 Nos.	220/ (0.9X0. 9X5X4. 2)=13Nos	280/ (0.9X0.9 X5X4.2) =17 Nos	160/ (0.9X0.9 X5X4.2) =10 Nos
(c)	For 08 hrs. load per day	104/ (0.9X0.9X 5X4.2)=0 7 Nos.	176/ (0.9X0. 9X5X4. 2)=11Nos	224/ (0.9X0.9 X5X4.2) =14 Nos	128/ (0.9X0.9 X5X4.2) =08 Nos
(d)	For 06 hrs. load per day	78/ (0.9X0.9X 5X4.2)=0 5 Nos.	132/ (0.9X0. 9X5X4. 2)=08 Nos	168/ (0.9X0.9 X5X4.2) =10 Nos	96/ (0.9X0.9 X5X4.2) =06 Nos
(vi)	No. of 12V, 70W Solar panel required	9	9	9	9

Sr. No.	Description	Upto 3 line station	Upto 4 line station	Upto 6 line station	Upto 4 line station with DC lit LED signal
(vii)	Total solar panel required (nos.)				
(a)	For 12 hrs. load per day	90	144	180	108
(b)	For 10 hrs. load per day	72	117	153	90
(c)	For 08 hrs. load per day	63	99	126	72
(d)	For 06 hrs. load per day	45	72	90	54
4.	**Area requirement for fixing solar panels (size approx. 1.2 mx0.55m per panel) in square meter**				
(a)	For 12 hrs. load per day	60	95	119	72
(b)	For 10 hrs. load per day	48	78	101	60
(c)	For 08 hrs. load per day	42	66	84	48
(d)	For 06 hrs. load per day	30	48	60	36
5.	**Approximate cost of solar panels (@ Rs. 15400/-)**				
(a)	For 12 hrs. load per day	14 lakhs	23 lakhs	28 lakhs	17 lakhs
(b)	For 10 hrs. load per day	11 lakhs	18 lakhs	24 lakhs	14 lakhs
(c)	For 08 hrs. load per day	10 lakhs	16 lakhs	20 lakhs	11 lakhs
(d)	For 06 hrs. load per day	07 lakhs	11 lakhs	14 lakhs	9 lakhs

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Note: Actual solar panel requirement shall be carried out by the Railway as per the guidelines given above in the table B based on actual signalling load at a station with IPS system.

Go to Index

Click for contents

Section III
Installation of Solar Panel

3.1 Introduction

Solar modules are to be installed firmly and permanently on metallic structures. The structures depend on the application and size of the system. For smaller systems like solar home systems, simple module mounting structures are used. For systems like solar streetlights, solar powered signal lighting, solar pumps etc. pole mounting module frames are used. For bigger systems like solar power plants and Solar powered Railway signalling installations, bigger array mounting structures are used.

3.2 Testing before installation

Before installation the solar panels are tested at the manufacturing unit to check for the following parameters:

- Voc-Open circuit voltage
- Isc-Short circuit current
- Vmax- Maximum Voltage
- Imax- Maximum Current
- Pmax- Maximum power at Standard Test Conditions or Peak Power Output.

The following table shows typical user's specifications of different modules:

Table B

Peak Power Output (Pmax)	Nominal Voltage	Open Circuit Voltage (Voc)	Short circuit Current (Isc)	Max. Voltage (Vmax) at Pmax	Max Current (Imax) at Pmax
4W	6V	>11.5V	>0.63A	8.5V	0.47A
4W	12V	>21V	>0.3A	16.7V	0.23A
8W	12V	>21V	>0.56A	16.7V	0.47A
10W	12V	>21V	>0.70A	16.7V	0.59A
12W	12V	>21V	>0.84A	16.7V	0.71A
18W	12V	>21V	>1.26A	16.7V	1.07A
35W	12V	>21V	>2.4A	16.7V	2.09A
40W	12V	>21V	>2.7A	16.7V	2.39A
50W	12V	>21V	>3.3A	16.7V	2.99A
65W	12V	>21V	>4.0A	16.7V	3.89A
70W	12V	>21V	>4.5A	16.7V	4.19A
75W	12V	>21V	>5.0A	16.7V	4.49A
90W	12V	>21V	>6.0A	16.7V	5.38A

Click for contents

The above values are at standard testing conditions such as 25-degree cell temperature and 100-mW/Sq.cm solar radiation. The output will be reduced as temperature rises and intensity of sunlight reduces. Although accurate power is measured with the help of Module Tester at supplier's end, however to check working of module Voc and Isc can be measured at site as shown in Fig.7 (a) & (b) by simple multimeter in two different modes i.e. Current mode and Voltage mode when module is placed in sunlight. The solar panel is kept in such a position that it receives maximum sunlight.

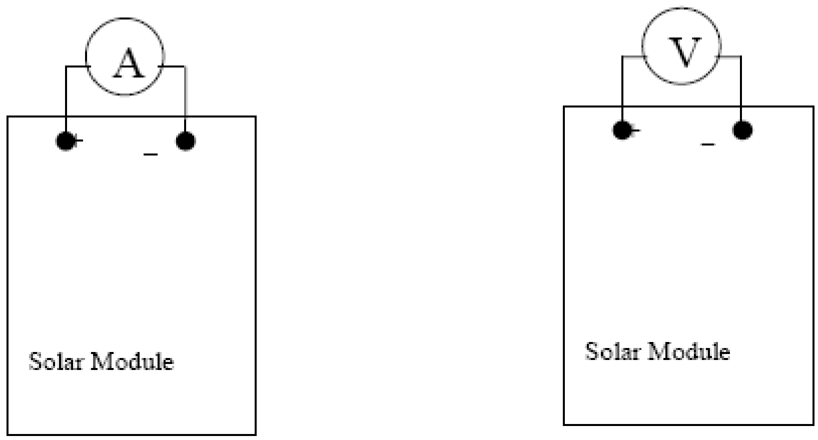

Fig.3.1: Testing before installation. Measurement of (a) Isc (b) Voc

The typical I-V curve of a 35-Watt module with 36 series connected cells is illustrated in Fig 8.

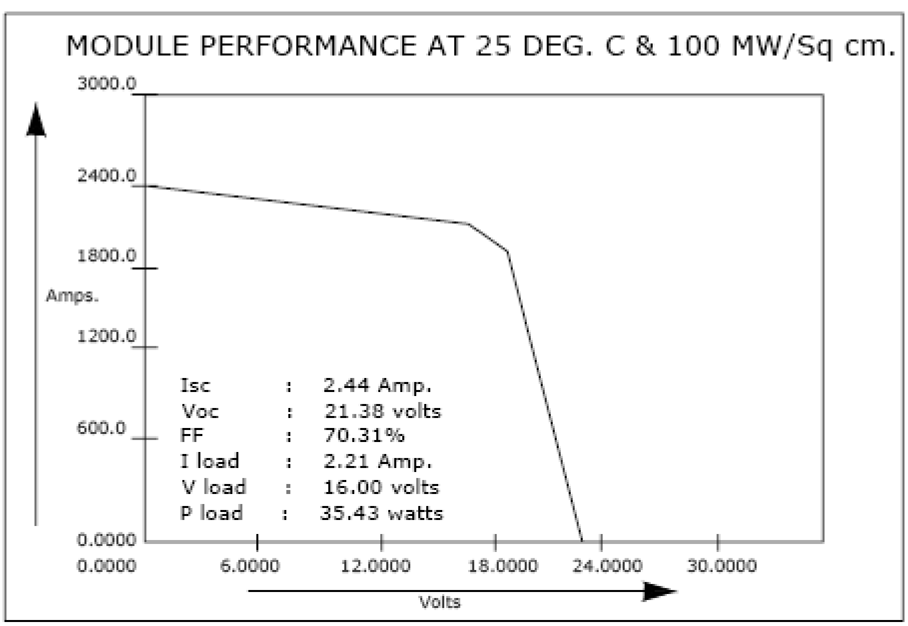

Fig.3.2: IV curve of a 35 Watt Solar Module

3.3 Installation guidelines

The installation of Solar Power System involves the following major steps:

- Civil Foundation Job
- Assembly and fixing of support structure.
- Mounting of Solar Modules on the Support Structure.
- Installation of Battery Bank.
- Interconnection of SPV panel in series & parallel configuration, Charge Control Unit and FJB
- Connection of Battery Bank and Load
- Earthing of Lightning Protection Unit.

3.3.1 Mounting the Solar Modules

For mounting the solar panels first determine mounting method i.e. Roof mount or Ground mount.

While mounting the solar Modules, following points should be considered for getting maximum output from the solar modules:

- Modules should be oriented south facing to receive maximum sunlight..
- The Modules produce more power at low temperature and full sun.
- Tracking the Sun increases the amount of power from an array

The Solar panels are generally installed in such a way that they can receive maximum direct sunlight without shade from any building/trees nearby falling on them at any part of the day.

As we know that the Sun rises in the East and sets in the West as a result of Earth's rotation around its own axis. Also the Earth revolves around the Sun. Due to these two movements there is variation in the angle at which the Sun's rays fall on Earth's surface over a year. At any particular place on Earth this variation in angle in one year may be upto 45 degrees. Considering these facts the following guidelines are to be kept in mind while installing solar panels:

1. Solar panels should be installed at an angle of '(LATITUDE of the place + 10) degree' from horizontal. For example, New Delhi has a latitude of 26 degree, hence any solar panel in New Delhi is to be installed at an angle of 26 + 10=36 degree inclined to horizontal.

2. Solar panels should be installed South facing in the Northern hemisphere and North facing in the Southern hemisphere. Since India is in the Northern hemisphere, Solar panels will be installed always- South facing in our country. The directions North-South may be found with the help of Magnetic Compass. The picture given in Fig 3.3 illustrates this.

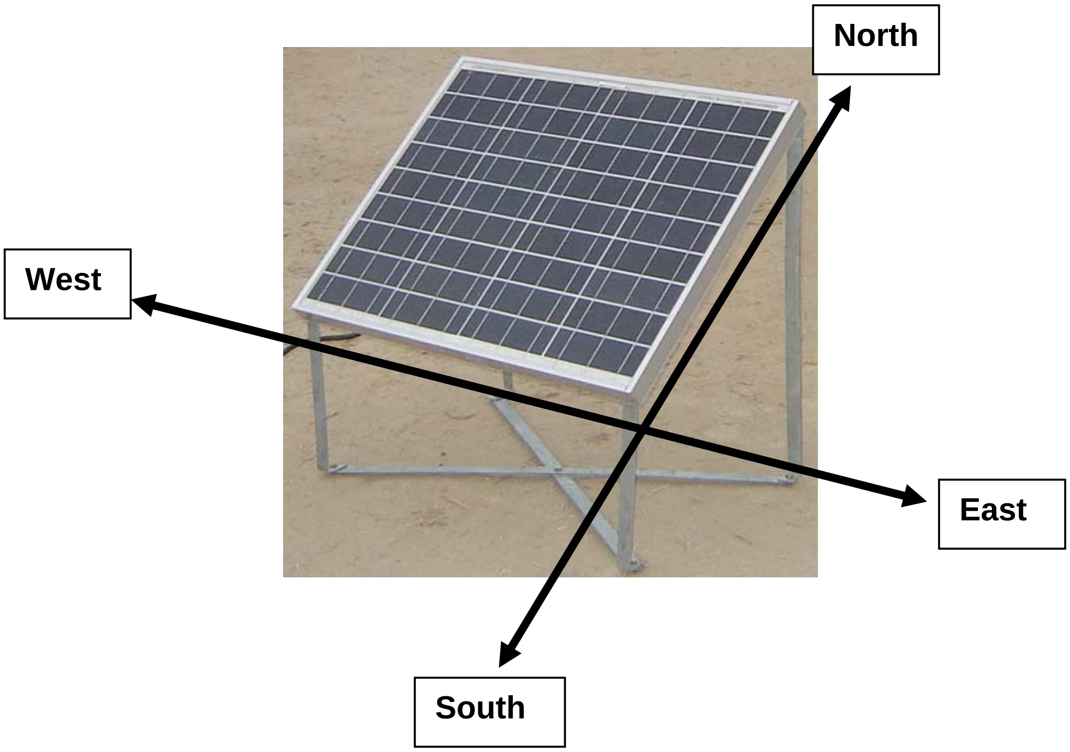

Fig.3.3: A Solar Panel installation

3. Any obstruction (such as tree or building) should be avoided in East, West or South of the place of installation. The following is the criteria:

(i) East or West: The distance between solar panel and obstruction should be more than double the height of obstruction.
(ii) South: The distance should be more than half the height of obstruction.

4. The support for the Solar panel need to be a robust one and should not be accessible to general public. It should be so installed that rainwater, bird dropping, leaves etc. do not accumulate and the top surface can be cleaned easily.

5. Calculate Tilt of Array

6. Calculate Space between Rows to avoid shadow.
   (i) Distance between adjacent rows of structures have to be maintained so that the shadow can be avoided.
   (ii) Calculate or measure panel height H.
   (iii) Locate the PV site Latitude.
   (iv) The minimum panel spacing W is given by the formula W = H X U
   (v) Where H is the vertical height of the panel from the base as shown in fig. below.
   (vi) U can be determined from the table C given below, corresponding to the latitude of PV site.

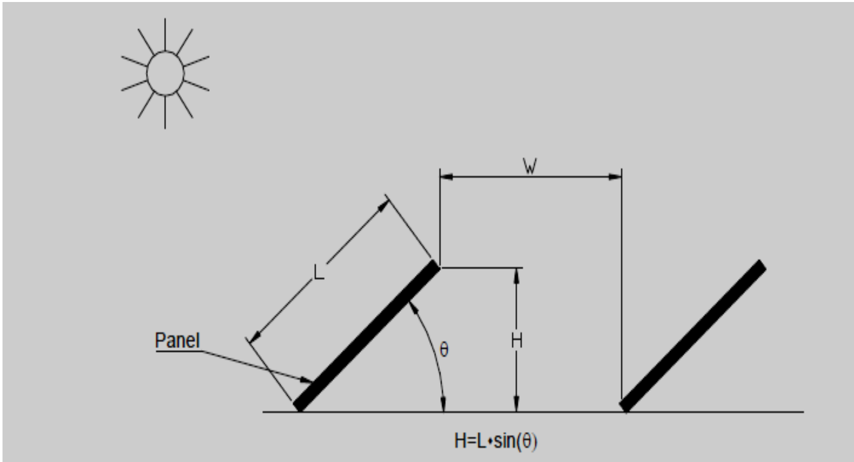

Fig.3.4: Sketch showing Panel Height, spacing between adjacent rows and angle of tilt

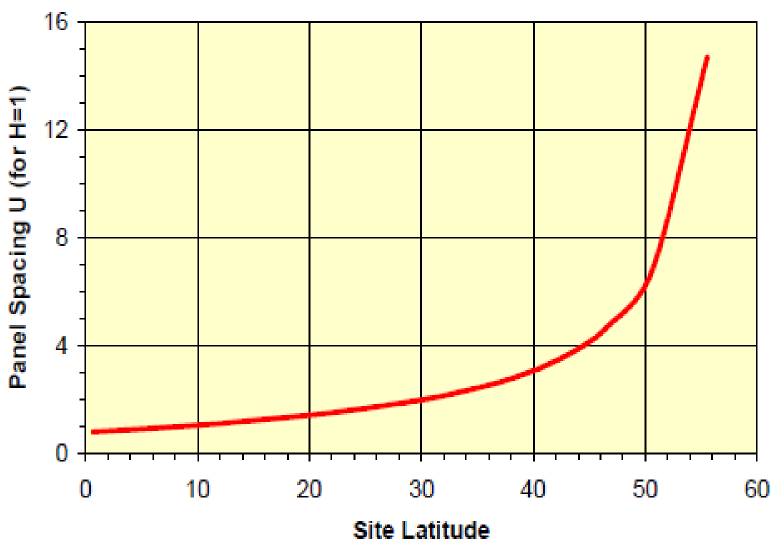

Fig.3.5: Panel spacing versus Site Latitude

Table C

Latitude	U
0	0.614
10	0.885
20	1.259
28	1.699
30	1.842
32	2.001
34	2.195
36	2.404
38	2.667
39	2.818
40	2.972
41	3.166
42	3.359
44	3.844
46	4.499
50	6.547
55	14.520

Fig.3.6: A solar panel installation

3.3.1 Electrical Interconnections

(i) Cables

1. Cable and terminal connectors are provided with the system
2. Required length of cable shall be cut and terminals to be crimped
3. Crimping tool to be used for crimping terminal to cable
4. Wire size shall be increased as the length of the cable increases.
5. All exposed wiring must be in conduits / capping-casing.
6. Wiring through roofing must be water proof.
7. Where the wiring is through flammable materials like thatched roof, they must be in a metal conduit.

(ii) Connections to the Solar module

Open the junction box of the module and connect the module cable with correct polarity.

Close the junction box and tie the module cable on the module frame.

Fig. 3.7(i): Opening of module junction box *Fig.3.7 (ii): Module cable with correct polarity*

Fig.3.7 (iii): Connecting module cable *Fig.3.7 (ii): Closing the junction box cover*

Click for contents

(iii) Interconnections between Charge controller and Solar Modules

For interconnections between charge controller and solar modules, the following general installation guidelines shall be followed:

- For interconnecting the SPV/Arrays with charge controller and battery bank, use minimum wire length so as to avoid the DC voltage drop in the line. At the same time care must be taken to ensure that no wires are hanged loose.
- Connect all modules in series & parallel conections.
- Use cable conductor size as given below to avoid voltage drop of the system:

(i) For Series connection of modules – 1 X 2.5 Sq. mm PVC sheathed unarmoured.

(ii) For Parallel connection of modules – 2 X 2.5 Sq. mm PVC sheathed unarmoured.

(iii) From FJB to Charge controller and Charge controller to Battery bank – 2 X 10 Sq. mm PVC sheathed unarmoured.

- Open the junction boxes (FJBs) and remove the fuses provided inside the junction boxes.

> ☞Note: Switch OFF MCB of Charge Controller before any connection.

- Connect Battery Positive (+) and Battery Negative (-) OF Charge Controller TO the Battery Bank.
- Next connect SPV-1 Negative (-) and SPV-1 Positive of Charge Controller.

> ☞Note: Charge Controller will be damaged if SPV Array is connected first and then the Battery bank.

- Battery connections must be given first to charge controller.
- Insert and replace all the fuses of junction boxes AFTER connecting all the cables to Charge Controller and to the battery bank of 110 V 300AH.
- Do not short negative terminals of the system.
- All the Positive (+) and Negative (-) wires will run separately from the junction boxes.

> ☞Note: Switch ON MCB of the Charge Controller when all the connections are thoroughly checked and fuses are replaced in the junction boxes.

Go to Index

Click for contents

Section IV

Maintenance & Troubleshooting

4.1 Maintenance

Solar panels require virtually no maintenance. However the associated equipments such as batteries and charge controller are to be maintained. Once a fortnight the surface of the panels should be wiped clean with wet rag to remove dust, fallen leaves, bird dropping etc. Only water to be used and no other cleaning agent.

With Solar Panel Secondary battery maintenance becomes minimum. Still general periodical maintenance of battery should be carried out in usual manner and as per maintenance manual.
For efficient working of SPV system certain precautions are to be observed as given below.

4.1.1 Precautions and Preventive Steps

Please ensure that:

a) SPV Modules are connected in parallel and SPV Panel output voltage is less than 25 Volts under normal sunshine condition (for 12 V System/Module)
b) All connections are properly made tight and neat using the crimped Red (for +ve) and Black (for –ve) wires supplied by the manufacturer in order to avoid reverse connection.
c) The rating of the fuse in the charge controller is not changed.
d) The SPV Panel is installed facing SOUTH and with the correct ‘Angle of tilt’.
e) There is no shadow on any part of the SPV Panel at any time of the day, to get maximum power.
f) SPV Modules are protected against any act of vandalism and accidental strike or hit by heavy objects, like stone, hammer etc. If the SPV Panel is installed on ground, it must be fenced properly to protect it from cattle and to prevent from any damage/theft. Fencing should be made in such a way that no shadow should fall on SPV Panel at any time of the day.
g) Battery Bank is placed on a rack or platform insulated from ground and located in a well-ventilated room and also sufficient clearance is there over the battery.
h) FIRST the Battery Bank, then SPV Panel and then Load is connected to SPV Charge Control Unit and for disconnection reverse sequence is adopted.
i) Battery terminals are never shorted even momentarily as shorting will result in HEAVY SPARK AND FIRE. (To avoid the same connect the cable at Charge Controller end ‘First’ and then Battery end.)
j) Never connect the Load directly to the SPV Panel as SPV Panel may give higher/lower voltage than required by the Load Equipment and hence the equipment may be DAMAGED permanently.
k) Blocking diode is provided at the array output for protection against reverse polarity.

l) Make sure that the Solar PV module gets direct sunlight throughout the day where you install it.
m) The Green indicator on Charge controller is only an indication for charging. It will glow even at small amount of charging. So to ensure efficient charging, the availability of direct sunlight over the Solar PV module for the maximum hours of the day should be ensured.
n) It is NOT HEAT BUT LIGHT that produces energy. So let direct sunlight to fall on the module surface without shades.

4.2 Troubleshooting

The SPV Power Source is reliable Source of Electrical energy. However, there may be rare instances, when the SPV Power Source is not able to drive the connected equipment.

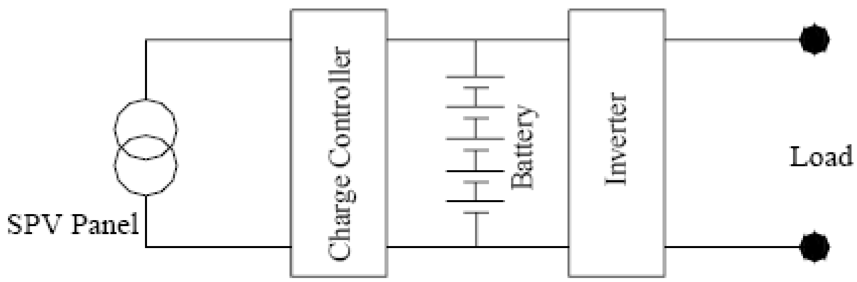

Fig. 4.1: SPV Power Source

The diagnosis of the problem in such situations starts with the battery. Check the voltage of the battery bank. If the voltage of the battery bank is correct as indicated in Charge controller, there may be problem in the inverter or switch between load and inverter i.e. either inverter is tripped or switch/load MCB is tripped or load fuse is blown off. If none of the above fault is observed then check the specific gravity of the electrolyte in the secondary cells of the battery. There may be two cases:

a) If the specific gravity is above the level 1.2 (Hydrometer reading 1200) value or as specified in the maintenance manual, it implies that the battery is in order and the problem would be either with the Charge Controller or Load. Disconnect the load (S & T Equipment) from Charge Controller and connect it directly to Battery Bank. If the equipment operates, the defect may be with the Charge Controller. Disconnect the Charge Controller and check as per troubleshooting instructions given in the manual supplied with it or inform the manufacturer/supplier.

b) If the specific gravity of the electrolyte is below the specified level and BATT/LOW (Red)) LED is glowing, the problem may be with any of the following:

i. Load: This may be drawing more current from the battery than required. In such case, battery is bound to get discharged, even if SPV Panel is functioning properly. This would result in frequent tripping of the load. To avoid this, get the load equipment checked and replace any defective components.

Click for contents

ii. SPV Panel: The SPV Panel may not be producing required power for which the Power Source has been designed. In that case, check the SPV Panel as given below:

- Check for any loose connection/breakage of wire in SPV module interconnections.
- If there is no such loose connection, clean the SPV Modules with soft cloth. Whenever there is bright sunshine, measure the voltage and current of each module after disconnecting the wire. Open circuit voltage of each module should be around 21 volts and short circuit current should be as per table given under Para 6 depending upon the wattage of the module, at 100 mW/Sq.cm AM 1.5 Solar radiation.
- If any of the SPV modules gives low voltage/current output during bright sunlight (Sun intensity 90 mW/Sq. cm) inform the manufacturer/Supplier with module serial number along with the measurement taken, for necessary investigations.

iii. Failure of blocking diode: Blocking diode fails in short circuit and open circuit mode. If it is failed in short circuit mode, voltage across its terminal will be zero in place of 0.7 V while charging current flows through it. When it fails in open circuit mode, the current will not flow through the diode. The diode may be checked as per standard method of checking of diode by removing from the circuit.

Apart from these some possible complaints and troubleshooting methods for Solar modules are listed in Table C below:

Table C

S. No.	Symptom	Possible Failure	Probable cause	Action
1.	No output	Cable	Conductor break	Replace cable
			Corrosion	
			Loose connection	
			Improper connection	Verify the wire connections are tight, corrosion free and of correct polarity.
		Connector	Defective connector	Replace connector
			Loose connection	
			Pin loose	
			Corrosion	
			Improper fixing	Fix the connector properly
		Junction box	Mechanical damage	Return to factory for Servicing
			Connection problem	Connect properly
		Charge controller	Electronic failure	Replace charge controller
		None of the above	Internal problem	Return to factory, if within warranty

S. No.	Symptom	Possible Failure	Probable cause	Action
2.	Output voltage OK, but no output current	Cell/interconnections	Internal damage	Return to factory, if Within warranty
3.	No charging indication on the Charge controller	Solar module	Shading	Remove the shades or change the location of the module and ensure maximum sunlight to fall on the module.
			Dirt accumulation	Clear the particles on the module
		Module cable	Breakage	Replace cable
			Corrosion	
			Dry solder	
			Loose connection	
		Module	Broken module	Replace module
		Charge controller	Electronic failure	Replace Charge controller
4.	Output voltage for less duration	Solar module	Shading	Remove the shades or change the location of the module and ensure maximum sunlight to fall on the module.
			Dirt accumulation	Clear the particles on the module
			Improper installation	Place the module in such a way that direct sunlight falls on the module for more hours.
		Module cable	Breakage	Replace cable
			Corrosion	
			Loose connection	
			Dry solder	
		Charge controller	Electronic failure	Replace Charge controller
			Corrosion	
		Battery	Insufficient charging	Charge the battery to full charge condition and check the output duration.
			Low capacity	Replace battery
			Acid leakage	
			Terminal broken	
5.	Always low battery condition	Solar module	Shading	Remove the shades or change the location of the module and ensure maximum sunlight to fall on the module.
			Dirt accumulation	Clear the particles on the module
		Battery	Insufficient charging	Charge the battery to full charge condition and check the output duration.
		Solar Module	Improper installation	Place the module in such a way that direct sunlight falls on the module for more hours.
		Module cable	Loose connection	Replace cable
			Improper fixing	Fix the cable properly and ensure that the connections are tight with correct polarity.

Click for contents
Click for contents

S. No.	Symptom	Possible Failure	Probable cause	Action
		Charge Controller	Electronic failure Corrosion	Replace the Charge controller
6.	Front Glass broken	Breakage	Mishandling/ transportation	Unserviceable, Replace
7.	No voltage Across blocking diode	Diode failed in short circuit mode	Random failure	Replace the diode
8.	Voltage high Across blocking diode	Diode failed in open circuit mode	Random failure	Replace the diode

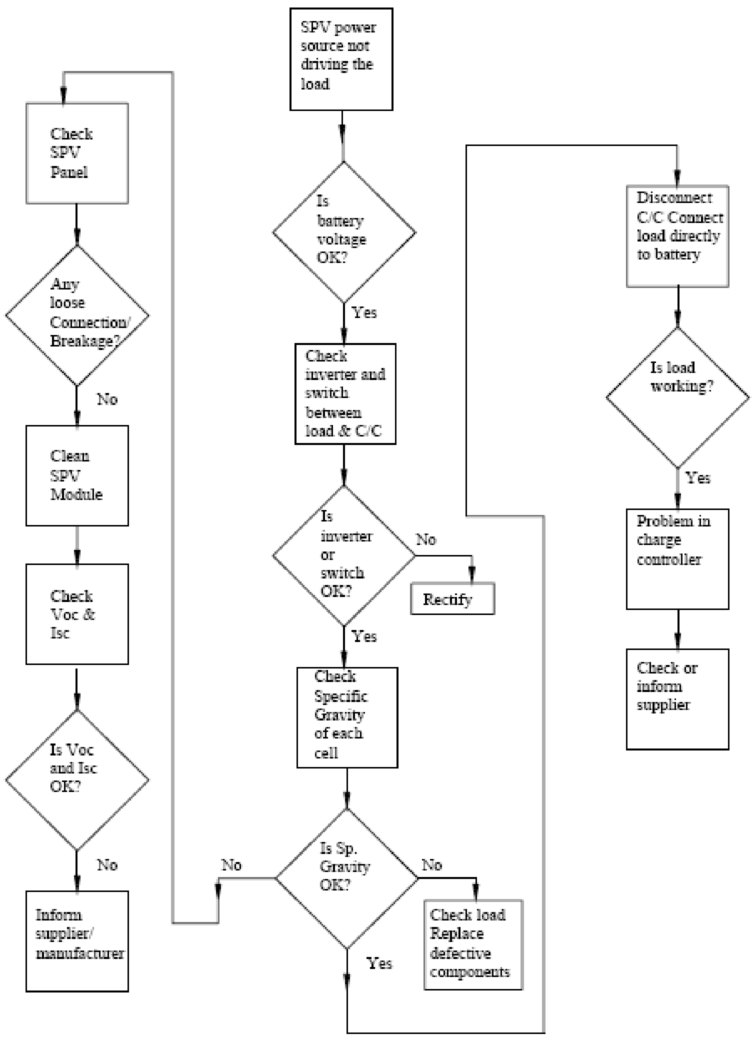

Fig. 4.2: Troubleshooting flowchart for SPV Panel